Modern shelters and limestone decay in archaeological sites – a study from Malta

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Mnajdra is one of three sheltered Temple complexes in the Maltese Islands. It is composed of both Globigerina Limestone and Coralline Limestone.
An overview of Globigerina Limestone, the historically widely used limestone in the Maltese Islands
(Episodes Vol. 40, No. 3, pp 221 – 231)

<table>
<thead>
<tr>
<th>Technical Properties:</th>
<th>Real density</th>
<th>2628 – 2800 kg/m³</th>
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<tr>
<td></td>
<td>Apparent density:</td>
<td>1630 - 1851 kg/m³</td>
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<td>Chemical analysis (average)</td>
<td>CaO: 49.71%; SiO₂: 4%; Al₂O₃: 1.18%; MgO: 0.71%; Fe₂O₃: 0.66%; below 0.5%: P₂O₅, K₂O, TiO₂, Na₂O, MnO</td>
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<td>Mineralogical analysis (average): calcite (up to 99%), quartz (up to 8%), feldspars (up to 1%), clay minerals (up to 12%)</td>
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<td>Porosity:</td>
<td>23.9 - 40.7 %</td>
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<td>Average pore radii:</td>
<td>0.56 - 1.06 μm</td>
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<td>Pore surface:</td>
<td>3.4 - 12.8 m².g⁻¹</td>
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<td>Water uptake rate (atm. pressure):</td>
<td>14.1 - 20.8 weight %</td>
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<td>Capillary water uptake w value:</td>
<td>3.1 - 9.6 kg.m⁻².h⁻¹/₂</td>
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<td>Saturation coefficient:</td>
<td>0.66 - 0.95</td>
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<td></td>
<td>Water vapour diffusion resistance:</td>
<td>7.78 - 7.83 (μ value)</td>
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<td>Hygric expansion:</td>
<td>0.20 - 0.25 mm m⁻¹</td>
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<td>Thermal dilatation coefficient:</td>
<td>2.32 - 4.51 K⁻¹</td>
</tr>
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</table>
Two current parallel areas of ongoing research

- Studies *in situ* and in the laboratory of **the effects of salt weathering on this porous stone** to represent, and eventually model, how the salts present within the megaliths are bringing about their deterioration.

- This is based on existing studies on Globigerina Limestone and its deterioration and environmental and related data collected over the years at the sites, both before and after sheltering.

- It **includes site data** such as thermal imaging, XRD-XRF, Raman, FTIR directly on the affected megaliths.

- Dust accumulation, and surrounding dust sources, are being sampled and studied, also by SEM.

- Actual **deteriorations patterns** are being mapped on a regular basis.

- Biological cover is also being mapped and studied, and compared to the pre-sheltering situation.

- **Environmental monitoring and the modelling of data (past and present)** are being carried out to understand how the microclimate has changed in (and around) the Temple sites since the erection of the shelters.

- These studies are based on a vast array of data collected at the sites over the years, which monitoring is still continuing.

- Data include: air T and RH, surface T, wind speeds and directions, solar load.
Deterioration issues at the Temples and the sheltering

- Advanced deterioration of the Globigerina megaliths is manifest as powdering, flaking, and alveolar weathering.
- Loss of infill from the double walled structure, and weakened megaliths, led to structural problems, including frequent collapses.
- Besides the intrinsic properties of this being a very porous stone, external causes include: marine aerosol, rising damp, thermoclastism, rainfall, wind abrasion.

- Three of these megalithic sites are now covered by a “temporary” open-sided shelter.
- These shelters are intended as a preventive conservation measure, to minimize the effects of environmental factors on the weakened, roofless structures.

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Studies on stone deterioration – concentrate primarily on one badly deteriorated apse
Thermal imaging is an important component of the study. Below are general comparisons in autumn/winter at Mnajdra.

Before sheltering

After sheltering
Wind flow and solar load are being modelled.
Ultimate aim

Working within a multidisciplinary team of scientists, engineers and archaeologists, the study has now entered its second year.

Current work at the Mnajdra Temple includes:

• *in situ* data being collected:
  • analysis of the megaliths themselves and their deterioration materials (portable analytical instruments)
  • thermal imaging (thermal camera)
  • environmental monitoring inside and outside with *in situ* sensors and a weather station
    • detailed wind measured with on site anemometers and LIDAR
  • supporting laboratory studies (e.g. of dust samples) by ESEM).

Integrating all the data (past and present) within the models being produced as well as amalgamation with the yearly condition maps of the megaliths will help to:

• quantify and record the effects of the shelters (through purposely produced models)
• understand the salt (and other) weathering of the porous limestone
• inform decisions for the future preservation of the sites.
We would be very happy to receive comments, and suggestions, from you to help move this research forward in the best possible way.

Results will have implications not only for archaeological sites, and historic buildings, in Malta, but could also apply to similar stone types in comparable environments.

This is a collaborative project led by the University of Malta, and fully supported by Heritage Malta. CNR-ISAC also participating.

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